FLATTENED TUBE HEAT EXCHANGER MADE FROM MICRO-CHANNEL TUBING

FIELD OF THE INVENTION

[0001] The present invention relates to a heat exchanger and, more specifically, relates to a heat exchanger that is made from flattened tubing which can be shaped into a variety of configurations to meet the needs of the particular application in which the heat exchanger will be used.

BACKGROUND OF THE INVENTION

[0002] Heat exchangers for use in refrigeration systems are well known and come in a variety of forms. For example, heat exchangers can be in the form of plate fin on tube heat exchangers and wire-on-tube heat exchangers.

[0003] The tube heat exchangers typically use 3/16" or 1/4" tubing with a passageway through the tubing that allows a fluid to travel through the tubing. Heat transfer fins are attached to the periphery of the tubing to facilitate heat transfer. Typical arrangements for the tubing include: 1) a serpentine configuration wherein the tubing snakes back and forth; 2) a coiled configuration wherein the tubing coils around itself and forms a series of generally concentric layers; and 3) a series of parallel tubes with manifolds on opposite ends so that the fluid can travel through the parallel tubes and exchange heat.

[0004] To facilitate heat transfer, these heat exchangers typically employ a plurality of heat transfer fins that extend along the periphery of the tubes. The fins are disposed between adjacent sections of the tubing and occupy the space between the

adjacent sections. The attaching of the heat transfer fins to the adjacent sections requires the fins to be attached to two or more surfaces. The attaching of the fins to two or more surfaces increases the cost of manufacturing the heat exchanger over the cost associated with manufacturing a heat exchanger having fins attached to a single section of tubing. Additionally, the attachment of the fins to the tubing is typically done after the tubing has been shaped into a desired configuration, such as a serpentine configuration. Because the desired configuration can encompass tight spaces with adjacent sections of tubing being very close, the attaching of the fins to the tubing can be a difficult and time consuming endeavor which increases the complexity of manufacturing the heat exchanger and the overall cost. Furthermore, in some applications, due to the limited space between adjacent sections of the heat exchanger tubing, insertion of the heat transfer fins into the spaces can be difficult and the fins can be damaged in the process thereby reducing the overall heat transfer efficiency of the resulting heat exchanger.

[0005] Finally, some prior art heat exchangers consist of a series of discrete tube segments that are assembled together to form a heat exchanger. The use of a number of discrete segments that must be assembled together to form the heat exchanger increases the complexity and cost of manufacturing the heat exchanger. Additionally, the use of a plurality of tube segments increases the number of connections that must be made and increases the possibility of having connections that leak.

[0006] Therefore, what is needed is a heat exchanger that is easier to manufacture, less complex, and less expensive. The heat exchanger should also be

capable of being shaped into a variety of configurations to meet the needs of different applications for the heat exchanger.

SUMMARY OF THE INVENTION

[0007] The present invention is directed to a flattened tube heat exchanger and a method of manufacturing the same, in accordance with the preferred embodiments of the present invention.

[0008] In one preferred embodiment, the flattened tube heat exchanger comprises a flattened tube having first and second ends with a length therebetween. The tube has opposite first and second heat transfer surfaces that extend from the first end to the second end. The tube is shaped into a predetermined configuration with portions of the heat transfer surfaces being adjacent to other portions of the heat transfer surfaces. The adjacent portions of the heat transfer surfaces are spaced apart so that a space exists between each of the adjacent portions of the heat transfer surfaces. The tube has at least one passageway that extends through the tube from the first end to the second end so that a fluid can pass through the tube. At least one heat transfer fin having first and second ends is conductively attached to one of the first or second heat transfer surfaces by attaching the first end of the at least one heat transfer fin to the heat transfer surface. The at least one heat transfer fin extends along a portion of the length of the tube that includes adjacent portions of the heat transfer surfaces. A portion of the second end of the at least one heat transfer fin extends into at least one of the spaces between adjacent portions of the heat transfer surfaces. First and second manifolds are attached to the respective first and second ends of the tube.

The first and second manifolds are in fluid communication with the respective first and second ends of the tube so that a fluid can pass between the first and second manifolds via the at least one passageway.

[0009] Preferably, the portion of the second end of the at least one heat transfer fin extends into at least one of the spaces between adjacent portions of the heat transfer surfaces without contacting the adjacent portion of the heat transfer surface. Optionally, but preferably, the at least one heat transfer fin extends along the entire length of the tube from the first end to the second end. Also preferably, the at least one heat transfer fin is one of a plurality of heat transfer fins and a portion of the second end of at least one heat transfer fin of the plurality of heat transfer fins extends into at least one of the spaces between adjacent portions of the heat transfer surfaces. It is preferred that at least one heat transfer fin of the plurality of heat transfer fins is conductively attached to the first heat transfer surface and a different at least one heat transfer fin of the plurality of heat transfer fins is conductively attached to the second heat transfer surface. The at least one heat transfer fin attached to the first heat transfer surface can extend along the entire length of the tube or just along a portion of the length of the tube. Additionally, the different at least one heat transfer fin attached to the second heat transfer surface can also extend along the entire length of the tube or just along a portion of the length of the tube.

[0010] Preferably, the at least one passageway is one of a plurality of passageways. The plurality of passageways are preferably hydraulically parallel. Optionally, but preferably, the at least one heat transfer fin is a corrugated heat transfer

fin. Also preferably, the flattened heat transfer tube is a continuous tube from the first end to the second end.

[0011] In an alternate embodiment, the predetermined configuration is a coil and the tube is coiled along the length with the first and second heat transfer surfaces being radially opposite. The coil configuration has radially adjacent heat transfer surfaces that are spaced apart so that a space exists between radially adjacent heat transfer surfaces. The first end of the at least one heat transfer fin is conductively attached to one of the first or second heat transfer surfaces and extends along a portion of the length of the tube that includes radially adjacent heat transfer surfaces. A portion of the second end of the at least one heat transfer fin extends into the space between the radially adjacent heat transfer surfaces. Optionally, but preferably, the tube can be coiled so that the tube has alternating straight portions and curved portions along the length. Even more preferably, the curved portions are 90 degree curves.

[0012] The method of making a flattened tube heat exchanger of the present invention includes the steps of: 1) providing a flattened tube having first and second ends with a length therebetween, opposite first and second heat transfer surfaces that extend from the first end to the second end, and at least one fluid passageway that extends through the tube from the first end to the second end; 2) providing at least one heat transfer fin having first and second ends; 3) attaching the at least one heat transfer fin to at least one of the first or second heat transfer surfaces so that the first end of the at least one heat transfer fin is conductively attached to the heat transfer surface and extends along a portion of the length of the tube; 4) attaching first and second manifolds to the respective first and second ends of the tube so that the first and second manifolds

are in fluid communication with the at least one passageway and a fluid can pass between the first and second manifolds via the at least one passageway; and 5) shaping the flattened tube into a predetermined configuration.

[0013] Optionally, but preferably, the step of shaping the flattened tube includes shaping the flattened tube so that portions of the heat transfer surfaces are adjacent to other portions of the heat transfer surfaces. The adjacent portions of the heat transfer surfaces are spaced apart so that a space exists between each of the adjacent portions of the heat transfer surfaces. A portion of the second end of the at least one heat transfer fin extends into at least one of the spaces between adjacent portions of the heat transfer surfaces. Optionally, the portion of the second end of the at least one heat transfer fin extends into at least one of the spaces between adjacent portions of the heat transfer surfaces without contacting the adjacent portion of the heat transfer surface.

[0014] Optionally, the step of providing a flattened tube includes providing a roll of continuous flattened tube. The step of providing at least one heat transfer fin includes providing a roll of a continuous corrugated heat transfer fin having first and second ends. The step of attaching the at least one heat transfer fin includes attaching the first end of the continuous corrugated heat transfer fin to at least one of the first or second heat transfer surfaces. The method can further include cutting the continuous flattened tube with the attached continuous corrugated heat transfer fin to a predetermined length prior to performing the step of attaching the first and second manifolds.

[0015] Optionally, the step of providing a flattened tube can include extruding the flattened tube. The step of attaching the at least one heat transfer fin includes attaching the at least one heat transfer fin to at least one of the first or second heat transfer surfaces while the flattened tube is being extruded. The flattened tube with the attached at least one heat transfer fin is cut to a predetermined length prior to performing a step of attaching first and second manifolds.

[0016] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0018] Figure 1 is a perspective view of a heat exchanger of the present invention;

[0019] Figure 2 is a front elevation view of the heat exchanger of figure 1;

[0020] Figure 3 is a side elevation view of the heat exchanger of figure 2;

[0021] Figure 4 is a perspective view of an alternate heat exchanger of the present invention;

[0022] Figure 5 is a front elevation view of the heat exchanger of figure 4;

[0023] Figure 6 is a side elevation view of the heat exchanger of figure 5;

[0024] Figure 7 is a perspective view of a different heat exchanger of the present invention;

[0025] Figure 8 is a front elevation view of the heat exchanger of figure 7;

[0026] Figure 9 is a side elevation view of the heat exchanger of figure 8;

[0027] Figure 10 is a cross-sectional view of a portion of the flattened tube used in the heat exchanger of figures 2, 5 and 8 along line 10-10 with the heat transfer fins removed;

[0028] Figure 11 is an enlarged perspective view of a portion of a corrugated heat transfer fin used on the heat exchangers of the present invention; and

[0029] Figure 12 is an elevation view of a portion of the corrugated heat transfer fin of figure 11.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0031] Referring to figure 1, there is shown a heat exchanger 20 in accordance with a preferred embodiment of the present invention. The heat exchanger 20 is generally comprised of a flattened tube 22, one or more heat transfer fins 24, and a pair of manifolds 26. The manifolds 26 communicate with the flattened tube 22 so that a fluid can flow from one of the manifolds 26 through the flattened tube 22 and out the other manifold 26.

[0032] As can be seen in figure 1, the flattened tube 22 has first and second ends 28, 30 and a length (not indicated) therebetween. Referring now to figure 10, a cross section of the flattened tube 22 is shown without the heat transfer fins 24. The flattened tube 22 has opposite sidewalls 32 and a width W therebetween. The sidewalls 32 separate opposite first and second heat transfer surfaces 34, 36. The sidewalls 32 and the first and second heat transfer surfaces 34, 36 extend along the length of the flattened tube 22 from the first end 28 to the second end 30. The sidewalls 32 are rounded, however, the sidewalls 32 could also be generally straight or take on a variety of shapes without departing from the scope of the invention as defined by the claims.

[0033] The flattened tube 22 has at least one passageway 38 that extends the length of the flattened tube 22 from the first end 28 to the second end 30. The at least one passageway 38 allows a fluid to flow through the flattened tube 22. Preferably, the at least one passageway 38 is one of a plurality of passageways 40 that extend from the first end 28 to the second end 30. Even more preferably, the plurality of passageways 40 are hydraulically parallel. As can be seen in figure 10, passageways 41 that are adjacent the sidewalls 32 are slightly larger than the central passageways 42. The passageways 41 that are adjacent the sidewalls 32 can take on a variety of forms and shapes that provide for ease of manufacture and efficient heat transfer along the sidewalls 32 and are not required to be identical to the central passageways 42 to be within the scope of the invention as defined by the claims. While the tube 22 has been and will continue to be described as a flattened tube, it should be understood that the term flattened tube should not be construed as being limited to a round tube that has been "flattened", but rather, the term flattened tube should be construed to include

tubing used in a heat exchanger that has opposite heat transfer surfaces along with at least one passageway that extends through the tube so that fluid can pass through the tube.

[0034] The flattened tube 22 with the plurality of passageways 40 is known in the art as a micro-channel tube. The hydraulic diameter of each of the plurality of passageways 40 is much smaller than that of typical tubing used in refrigeration system heat exchangers. For example, the hydraulic diameter of the typical tubing (3/16" and 1/4" inch O.D.) used in a refrigeration system condenser is 0.14" for 3/16" tubing and 0.20" for 1/4" tubing. While the typical hydraulic diameter of the passageways 40 in the flattened tube 22 range from approximately 0.050" to approximately 0.075". Because the hydraulic diameter of each of the passageways 40 of the flattened tube 22 are so much smaller than that of the typical tubing used in refrigeration systems, the conductive heat transfer coefficient of the flatten tube 22 is much greater than in typical refrigeration system tubing.

[0035] The flattened tube 22 is typically extruded, as is known in the art. The extrusion process yields a flattened tube 22 that is continuous and seamless. The extruded flattened tube 22 can be cut to any desired length. The length of the flattened tube 22 is dependent upon the application in which the heat exchanger 20 is to be used. The flattened tube 22 can be provided on a roll so that the flattened tube 22 can be pulled from the roll and cut to any desired length. The ease with which the flattened tube 22 can be cut to a desired length facilitates the efficient assembly of a heat exchanger 20 for any given application. Additionally, because the flattened tube 22 is continuous and can be cut to a desired length, the need to stock flattened tubes of

various lengths for the various applications within which the heat exchanger 20 could be used is avoided. The use of the continuous extruded flattened tube 22 thereby reduces the amount of inventory of flattened tubes that must be kept on hand and reduces the overall cost of making and providing a heat exchanger 20 in accordance with the present invention.

[0036] To facilitate heat transfer, the flattened tube 22 is constructed out of material with high thermal conductivity, as is known in the art. Additionally, because the flattened tube 22 will be shaped to a desired configuration, the flattened tube 22 needs to be capable of being easily bent. Therefore, it is preferred that the material of construction of the flattened tube 22 be mallable so that the flattened tube can be shaped into the desired configuration without breaking or cracking. For example, the flattened tube 22 can be made from aluminum or copper. However, it should be understood that numerous materials possess sufficient qualities to be used to construct the flattened tube 22. Therefore, while the flattened tube 22 has been described by reference to specific materials and properties, it should be understood that a variety of materials can be used to make the flattened tube 22 and still be within the scope of the invention as defined by the claims.

[0037] The heat exchanger 20 has at least one heat transfer fin 24 conductively attached to one of the first or second heat transfer surfaces 34, 36. As can be seen in figures 11 and 12, the at least one heat transfer fin 24 has opposite first and second ends 43, 44. The at least one heat transfer fin 24 is attached to one of the first or second heat transfer surfaces 34, 36 by attaching the first end 43 to the heat transfer surface. The heat transfer fin 24 extends along a portion of the length of the flattened

tube 22. Preferably, the fin 24 extends along a portion of the length of the tube 22 that includes adjacent portions of the heat transfer surfaces (as will be discussed below). The heat transfer fin 24 has a width 45 and a height 46. The width 45 of the heat transfer fin 24 extends across a portion of the width W of the flattened tube 22. Preferably, the width 45 of the heat transfer fin extends across the entire width W of the flattened tube 22. The height 46 of the heat transfer fin 24 is defined by the distance that the heat transfer fin 24 extends from the heat transfer surface and may coincide with the distance between the first and second ends 43, 44, depending upon the angle at which the heat transfer fin 24 extends from the heat transfer surface.

[0038] Preferably, the heat transfer fin 24 is a corrugated or accordion type heat transfer fin. The corrugated heat transfer fin 24 has peaks 47 and troughs 48 that coincide with the second and first ends 44, 43 of the heat transfer fin 24 respectively. The corrugated heat transfer fin 24 is attached to one of the heat transfer surfaces 34, 36 with the troughs 48 in contact with the heat transfer surface. The contact between the troughs 48 and the heat transfer surface 34, 36 allows heat to be conductively transferred between the flattened tube 22 and the heat transfer fin 24 so that the heat exchanger 20 can operate. Preferably, the troughs 48 of the heat transfer fin 24 are attached to the first or second heat transfer surface 34, 36 by brazing. Alternatively, the troughs 48 can be attached with a conductive adhesive. While the heat transfer fins 24 are preferably attached to the flattened tube 22 by brazing or a conductive adhesive, it should be understood that other means, as are known in the art, such as mechanical means, can be employed without departing from the scope of the invention as defined by the claims. The heat transfer fin 24 can be brazed to the flattened tube 22 at the

time the flattened tube 22 is being extruded. While the heat transfer fins 24 on the heat exchanger 20 have been shown and described as being preferably corrugated heat transfer fins 24, it should be understood that the heat transfer fins 24 could be individual heat transfer fins, as is known in the art, without departing from the scope of the invention, as defined by the claims.

[0039] The corrugated heat transfer fins 24 can come in preset lengths or can come in a continuous roll that can be cut to a desired length. The heat transfer fin 24 is preferably made from a material with high thermal conductivity so that efficient heat transfer can be attained. For example, the corrugated heat transfer fins 24 can be made out of aluminum, copper or steel. However, it should be understood that other materials, as are known in the art, can be utilized without departing from the scope of the invention.

[0040] Preferably, the at least one heat transfer fin 24 is attached to one of the first or second heat transfer surfaces 34, 36 and extends along a portion of the length of the flattened tube 22. Even more preferably, the at least one heat transfer fin 24 extends along the entire length of the flattened tube 22 from the first end 28 to the second end 30. When the at least one heat transfer fin 24 is one of a plurality of heat transfer fins 24, it is preferred that at least one heat transfer fin 24 of the plurality of heat transfer fins 24 is conductively attached to the first heat transfer surface 34 and a different at least one heat transfer fin 24 of the plurality of heat transfer fins 24 is conductively attached to the second heat transfer surface 36. The heat transfer fins 24 attached to the first and second heat transfer surfaces 34, 36 extend along various portions of the length of the flattened tube 22 between the first end 28 and the second

end 30 depending upon the needs of the application in which the heat exchanger 20 is being used. In the heat exchanger 20 shown in figure 1, the heat transfer fins 24 extend along both the first and second heat transfer surfaces 34, 36 the entire length of the flattened tube 22 between the first end 28 and the second end 30. The heat exchanger 20 thereby provides a relatively large heat transfer area through which heat transfer can occur.

[0041] The first and second heat transfer surfaces 34, 36 define the primary surface area of heat exchanger 20 through which heat transfer can occur. The surface area of the heat transfer fins 24 define a secondary surface area of the heat exchanger 20 through which heat transfer can occur. The present invention provides a ratio between the secondary surface area and the primary surface area that is much greater than that of conventional heat exchangers, such as plate-fin and tube, and wire-on-tube heat exchangers. The heat exchanger 20 of the present invention thereby provides a greater heat transfer rate with a lesser amount of primary surface area then prior art conventional heat exchangers. Because the cost of the primary surface area tends to be more expensive than the cost of the secondary surface area, the heat exchanger 20 can provide a less expensive heat exchanger with an equivalent or better heat transfer rate than that of a conventional heat exchanger.

[0042] While the above description of the heat transfer fins 24 and the positioning of the heat transfer fins 24 on the flattened tube 22 of the heat exchanger 20 have been described and shown with reference to specific embodiments, it should be understood that variations in these embodiments, as are known in the art, can be employed without departing from the scope of the invention as defined by the claims.

For example, the heat transfer fins 24 can come in a variety of shapes and sizes, as is known in the art, and still be within the scope of the invention. The heat transfer fins 24 can also be positioned differently on the flattened tube 22 and oriented differently, as is known in the art, and still be within the scope of the invention. It should also be understood that the heat transfer fin(s) 24 can be integral to the flattened tube 22. That is, the flattened tube 22 can have one or more heat transfer fins 24 that extends from at least one of the first or second heat transfer surfaces 34, 36 and is formed at the time the flattened tube 22 is extruded and still be within the scope of the invention as defined by the claims. When the heat transfer fins(s) 24 are integral to the first and/or second heat transfer surfaces 34, 36 of the flattened tube 22, it should be understood that the heat transfer fin(s) 24 can be continuous or intermittent along the first and/or second heat transfer surfaces 34, 36 as will be apparent to those skilled in the art.

[0043] A pair of manifolds 26 are attached to the flattened tube 22 of the heat exchanger 20. A first manifold 50 is attached to the first end 28 of the flattened tube 22. The first manifold 50 is attached to the first end 28 so that a passageway 51 in the first manifold 50 is in fluid communication with the plurality of passageways 40 in the flattened tube 22. The second manifold 52 is attached to the second end 30 of the flattened tube 22 so that a passageway 53 in the second manifold 52 is in fluid communication with the plurality of passageways 40 in the flattened tube 22. The fluid communication between the manifolds 50, 52 and the plurality of passageways 40 enables a fluid to pass between the first and second manifolds 50, 52 via the plurality of passageways 40. The first and second manifolds 50, 52 can come in a variety of shapes, such as circular tubes, rectangular tubes, and the like, as is known in the art.

The first and second manifolds 50, 52 can also be attached to other heat exchangers (not shown) so that the heat exchanger 20 is in series with other heat exchangers (not shown) or is in parallel with other heat exchangers (not shown), as is known in the art.

[0044] The heat exchanger 20 can be shaped into a variety of configurations. Preferably, the heat exchanger 20 is shaped into a configuration with portions 54 of the heat transfer surfaces 34, 36 being adjacent to other portions 54 of the heat transfer surfaces 34, 36. The adjacent portions 54 of the heat transfer surfaces 34, 36 are spaced apart so that a space 58 exists between each of the adjacent portions 54 of the heat transfer surfaces 34, 36. The heat exchanger 20 is shaped so that the at least one heat transfer fin 24 that is attached to one of the first or second heat transfer surfaces 34, 36 extends from the heat transfer surface 34, 36 into at least one of the spaces 58 between adjacent portions 54 of the heat transfer surfaces 34, 36. Preferably, the heat exchanger 20 is shaped so that the at least one heat transfer fin 24 that is attached to one of the first or second heat transfer surfaces 34, 36 extends from the heat transfer surface 34, 36 into at least one of the spaces 58 between adjacent portions 54 of the heat transfer surfaces 34, 36 without contacting the adjacent portion 54 of the heat transfer surface 34, 36 or a heat transfer fin 24 on the adjacent portion 54 of the heat transfer surface 34, 36. The extending of the at least one heat transfer fin 24 into at least one of the spaces 58 between adjacent portions 54 of the heat transfer surfaces 34, 36 positions a portion of the second end 44 of the at least one heat transfer fin 24 into at least one of the spaces 58 between adjacent portions 54 of the heat transfer surfaces 34, 36. Preferably, the second end 44 of the at least one heat transfer fin 24

does not contact the adjacent portion 54 of the heat transfer surface 34, 36 or a heat transfer fin 24 on the adjacent portion 54 of the heat transfer surface 34, 36.

[0045] Preferably, when a plurality of heat transfer fins 24 are utilized in the heat exchanger 20, the plurality of heat transfer fins 24 are attached to the flattened tube 22 so that there is at least one heat transfer fin 24 on the first heat transfer surface 34 and there is a different at least one heat transfer fin 24 on the second heat transfer surface 36. A number of the heat transfer fins 24 of the plurality of heat transfer fins 24 extend into the spaces 58 between adjacent portions 54 of the heat transfer surfaces 34, 36 so that portions of the second ends 44 of the number of heat transfer fins 22 are in the spaces 58. It is preferred that the second ends 44 of each heat transfer fin 24 of the number of heat transfer fins 24 that extend from the heat transfer surface 34, 36 and into at least one of the spaces 58 do not contact the adjacent portion 54 of the heat transfer surface 34, 36 or a heat transfer fin 24 on the adjacent portion 54 of the heat transfer surface 34, 36.

[0046] As can be seen in figures 1 and 2, when the heat exchanger 20 is shaped into a coil configuration, the flattened tube 22 is coiled along the length. The coiling of the flattened tube 22 along the length makes the first and second heat transfer surfaces 34, 36 radially opposite. Preferably, the flattened tube 22 is coiled so that radially adjacent heat transfer surfaces 34, 36 are spaced apart with a space 58 existing between the radially adjacent heat transfer surfaces 34, 36. The at least one heat transfer fin 24 is attached to one of the first or second heat transfer surfaces 34, 36 and extends from the heat transfer surface 34, 36 and into the space 58 between a radially

adjacent heat transfer surface 34, 36 without contacting the radially adjacent heat transfer surface 34, 36.

[0047] Optionally, the heat exchanger 20 can be coiled along its length so that the first end 28 of the flattened tube 22 is in a central portion 60 of the coiled heat exchanger 20 and the second end 30 of the flattened tube 22 along a periphery 62 of the coiled heat exchanger 20. Preferably, the heat exchanger 20 is coiled so that the flattened tube 22 has alternating straight portions 64 and curved portions 66 along the length. Even more preferably, the curved portions 66 are 90 degree curves so that the heat exchanger 20 can be easily shaped into the coil configuration shown in figures 1 and 2.

[0048] While the heat exchanger 20 has been discussed and shown as being coiled with flattened tube 22 having alternating straight portions 64 and curved portions 66, it should be understood that the heat exchanger 20 can be coiled along the length by having the first end 28 of the flattened tube 22 in the central portion 60 of the heat exchanger 20 and the flattened tube 22 spiraling around the central portion 60 with the second end 30 of the flattened tube 22 being on a periphery 62 of the heat exchanger 20 and still be within the scope of the invention as defined by the claims. The resulting spiral shape (not shown) for the heat exchanger 20 would consist of the flattened tube 22 continuously curving along its length to form a spiral configuration, as is known in the art.

[0049] As was discussed above, when the heat exchanger 20 is shaped into a coil configuration, it is preferred that the at least one heat transfer fin 24 that is attached to one of the first or second heat transfer surfaces 34, 36 extend from the heat transfer

surface 34, 36 into the space 58 between a radially adjacent heat transfer surface 34, 36 without contacting the radially adjacent heat transfer surface 34, 36 or a heat transfer fin 24 attached to the radially adjacent heat transfer surface 34, 36.

[0050] As can be seen in figures 4, 5, 7 and 8, the heat exchanger 20 can also be shaped into a serpentine configuration. The serpentine configuration has the flattened tube 22 snaking back and forth in a repetitive pattern with portions 54 of the heat transfer surfaces 34, 36 being adjacent and spaced apart so that a space 58 exists between the adjacent portions 54. The heat transfer fins 24 are attached to the heat transfer surfaces 34, 36 so that the heat transfer fins 24 extend into at least one of the spaces 58. Preferably, the heat transfer fins 24 are attached to the heat transfer surfaces 34, 36 so that the heat transfer fins 24 extend into at least one of the spaces 58 without contacting the adjacent portion 54 or heat transfer fin 24 on the adjacent portion 54. Preferably, the serpentine configuration consists of the flattened tube 22 having alternating straight portions 64 and curved portions 66. Preferably, the curved portions 66 are 180 degree curves.

[0051] While the heat exchanger 20 has been shown and described as being shaped into a coil or serpentine configuration, it should be understood that these specific configurations are for exemplary purposes and that the heat exchanger 20 can be shaped into a myriad of configurations and still be within the scope of the invention as defined by the claims. Therefore, the specific examples should not be viewed as limiting the scope of the invention which is defined by the claims.

[0052] Preferably the heat exchanger 20 is used as a condenser in a refrigeration system. However, the heat exchanger 20 can also be used in a variety of

other heat exchange applications, as is will be apparent to those skilled in the art. For example, the heat exchanger 20 can be used as an evaporator in a refrigeration system and as a liquid to air heat exchanger. Therefore, the heat exchanger 20 should not be construed as being limited to condensers.

[0053] The method of manufacturing the flattened tube heat exchanger 20 of the present invention includes the step of shaping the flattened tube 22 to a predetermined configuration. While there are a number of configurations that will have wide spread applicability to various applications, the shape of the predetermined configuration is primarily dependent upon the application in which the heat exchanger 20 is to be used. The factors that influence the predetermined configuration may include but are not limited to: the space available, the desired heat transfer rate, the cost, the pressure of the fluids, the allowable pressure drop across the heat exchanger 20, etc. Therefore, the specific configuration of the heat exchanger 20 may vary with the application in which the heat exchanger 20 is to be used.

[0054] Preferably, the step of shaping the flattened tube 22 includes shaping the flattened tube 22 so that portions 54 of the heat transfer surfaces 34, 36 are adjacent to other portions 54 of the heat transfer surfaces 34, 36, with the adjacent portions 54 of the heat transfer surfaces 34, 36 being spaced apart so that a space 58 exists between each of the adjacent portions 54 of the heat transfer surfaces 34, 36, and the at least one heat transfer fin 24 extends from the heat transfer surface 34, 36 into at least one of the spaces 58 between adjacent portions 54 of the heat transfer surfaces 34, 36. Even more preferably, the at least one heat transfer fin 24 extends from the heat transfer surface 34, 36 into at least one of the spaces 58 between

adjacent portions 54 of the heat transfer surfaces 34, 36 without contacting the adjacent portion 54 of heat transfer surface 34, 36 or a heat transfer fin 24 on the adjacent portion 54 of the heat transfer surface 34, 36.

[0055] Optionally, the step of providing the flattened tube 22 includes providing a roll of continuous flattened tubing 22, the step of providing at least one heat transfer fin 24 includes providing a roll of a continuous corrugated heat transfer fin 24 having first and second ends 43, 44, and the step of attaching the at least one heat transfer fin 24 includes attaching the first end 43 of the continuous corrugated heat transfer fin 24 to at least one of the first or second heat transfer surfaces 34, 36. When the flattened tube 22 is provided as a roll of continuous tubing 22, the flattened tube 22 can be removed from the roll and cut to a desired length. The flattened tube 22 can be cut to the desired length prior to attaching the at least one heat transfer fin 24 or cut to the desired length after the at least one heat transfer fin 24 is attached to the flattened tube 22. When the flattened tube 22 is cut after the at least one heat transfer fin 24 is attached to the flattened tube 22, the cutting of the flattened tube 22 would also cut the at least one heat transfer fin 24 if the at least one heat transfer fin 24 extends along the portion of the flattened tube 22 where the flattened tube 22 is to be cut. When the at least one heat transfer fin 24 is a continuous corrugated heat transfer fin 24 that extends along the entire length of the flattened tube 22, the above method provides for a simple economical method of providing a flattened tube 22 with a continuous corrugated heat transfer fin 24 that can be cut to any predetermined length so that a heat exchanger 20 can be constructed for a given application. The step of cutting the flattened tube 22 is performed prior to the step of attaching the first and second

manifolds 50, 52. However, because the roll of continuous tubing 22 will have a free end, it is possible to attach one of the manifolds 50, 52 to the flattened tube 22 prior to cutting the flattened tube 22.

[0056] Optionally, the step of attaching the at least one heat transfer fin 24 can comprise attaching the at least one heat transfer fin 24 to at least one of the first or second heat transfer surfaces 34, 36 while the flattened tube 22 is being extruded. The attaching of the at least one heat transfer fin 24 to the flattened tube 22 as the flattened tube 22 is being extruded eliminates the need to perform this operation as an additional process step. The extruded flattened tube 22 with the attached at least one heat transfer fin 24 is then cut to the desired length for the given application.

[0057] As was discussed above, the at least one heat transfer fin 24 can be one of a plurality of heat transfer fins 24. Preferably, at least one heat transfer fin 24 of the plurality of heat transfer fins 24 is attached to the first heat transfer surface 34 and a different at least one heat transfer fin 24 of the plurality of heat transfer fins 24 is attached to the second heat transfer surface 36. Preferably, the flattened tube 22, as was discussed above, can then be shaped into the predetermined configuration with the second ends 44 of the plurality of heat transfer fins 24 not contacting adjacent portions 54 of the heat transfer surfaces 34, 36 or other heat transfer fins 24 attached to the adjacent portions 54.

[0058] The step of shaping the flattened tube 22 to a predetermined configuration can be performed by bending the flattened tube 22 at various locations along the length of the flattened tube 22. Alternatively, the flattened tube 22 can be continuously bent along its length depending upon the application in which the heat

exchanger 20 will be used and the desired configuration. As is shown in figures 1, 2, 4, 5, 7 and 8, the heat exchanger 20 can be formed by bending the flattened tube 22 so that the length of the flattened tube 22 is comprised of alternating straight portions 64 and curved portions 66. However, it should be understood that the flattened tube 22 can be shaped into other configurations and by other means as are known in the art, without departing from the scope of the invention as defined by the claims. The shaping of the flattened tube 22 into the predetermined configuration after the heat transfer fins 24 have been attached to the flattened tube 22 allows for the easy and simple manufacture of the heat exchanger 20. That is, it is easier to attach the heat transfer fins 24 to the flattened tube 22 prior to bending the flattened tube 22 then it is to attach the heat transfer fins 24 to the flattened tube 22 after the flattened tube 22 has been shaped into the predetermined configuration which would require bending the heat transfer fins 24 to fit along the contours of the flattened tube 22 and then attaching the heat transfer fins 24 to the flattened tube 22. Therefore, the above method provides a heat exchanger 20 that is economical and easy to manufacture.

[0059] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.